

ELECTRO-OPTICAL APPARATUS AND PROJECTOR

BACKGROUND OF THE INVENTION1. Field of Invention

5 [0001] The present invention relates to an electro-optical apparatus that includes a liquid crystal panel, and a projector that employs the electro-optical apparatus.

2. Description of Related Art

10 [0002] Projectors are known that separate a light beam emitted from a light source into beams of three colors, RGB, through a dichroic mirror, modulate the respective beams of colors on the basis of image information through three liquid crystal panels, synthesize the modulated light beams through a cross-dichroic prism, and expand and project a color image through a projection lens.

15 [0003] This type of projector is fabricated by combining components, including an inner case, a liquid crystal panel, a prism, and a projection lens. In the assembly process, where dust or fluff may electrostatically adhere to an image forming region of an electro-optical apparatus formed of liquid crystal panels, and the shadow of the dust or fluff may be projected onto a projection surface, leading to deterioration of image quality.

20 [0004] Furthermore, after the delivery of a product, when a user uses the product, minute dust passing through an air filter, or dust or fluff that has accumulated in the inner case during a manufacturing process, is blown up by a cooling fan and adheres to the liquid crystal panels. The shadow of the dust or fluff may also be projected on an image, leading to deterioration of image quality.

SUMMARY OF THE INVENTION

25 [0005] If dust or fluff adheres to an electro-optical apparatus after assembly as mentioned above, then it is necessary to disassemble a projector body to remove the dust or fluff by using various types of equipment, such as an air gun, a blower, and a dust collector, and reassemble the projector body thereafter. This is required because the gap between the liquid crystal panels constituting the electro-optical apparatus and
30 the prism is so narrow that it is difficult to blow air in by an air gun or similar apparatus. Furthermore, the dust or fluff electrostatically adhering to the

09891405-062701
T02290-90476860

electro-optical apparatus cannot be easily removed, and it takes a long time to remove it. In addition, considerable equipment is necessary to remove dust or fluff.

[0006] Furthermore, in order to prevent the deterioration of image quality, it is substantially essential to provide the electro-optical apparatus with dust-proof glass to blur the shadow of dust projected onto an image. The dust-proof glass is used to shift the surface, to which dust or the like adheres, from the focal position of a projection lens so as to make the dust less conspicuous on a projection surface, even if dust or the like adheres to a surface (one surface or both surfaces) of a liquid crystal panel or the like.

[0007] Attempts to prevent the deterioration of image quality caused by dust or the like have been difficult because complicated work or considerable equipment is required and the number of components is increased in some cases, and manufacturing or maintenance costs are higher.

[0008] An object of the present invention is to provide an electro-optical apparatus and a projector that reduce such complicated work, considerable equipment, and an increase in the number of components, enable efficient manufacture and maintenance, and permit a reduction in manufacturing cost or maintenance cost.

[0009] To this end, according to the present invention, an electro-optical apparatus is provided that is equipped with a pair of substrates and an electro-optical element sandwiched between the pair of substrates. An antistatic layer is provided on the outer surface of at least one of the pair of substrates.

[0010] According to the present invention, since the antistatic layer is formed on the surface of the substrate, even if static electricity is generated on the surface of the substrate, the static electricity escapes to the exterior of the apparatus through the antistatic layer. Thus, electrification to the substrates of the electro-optical apparatus can be reduced, making it possible to minimize the adherence of dust, fluff, or the like to a surface of a substrate. This minimizes deterioration of images caused by the adherence of dust, fluff, or the like during a manufacturing process or during the use by a user.

[0011] Moreover, the above feature obviates the need for or simplifies the work required to remove dust, fluff, or the like from a substrate of an electro-optical apparatus and the need for equipment required therefor. Hence, the manufacture and

maintenance of the electro-optical apparatus can be efficiently performed, and the cost required for the manufacture and maintenance can be reduced.

[0012] In addition, the need for dust-proof glass, which has hitherto been substantially essential, can be obviated. If the need for the dust-proof glass is obviated, then the number of components can be reduced, so that the manufacturing cost can be reduced from this respect also.

[0013] Furthermore, since the electrification to a substrate can be reduced, in the case of an electro-optical device equipped with a TFT (thin-film transistor) device or the like, the destruction of the TFT device attributable to electrical discharge can be prevented, and defects in a manufacturing process can be reduced.

[0014] In the above, in the present invention, the antistatic layer is preferably formed of an inorganic material. The inorganic material may be exemplified by a composition provided with silica and conductive particulates.

[0015] An organic material can be used for the antistatic layer; however, the organic material may cause a problem, such as deterioration or discoloration attributable to light. In contrast thereto, forming the antistatic layer by an inorganic material solves the problem with an organic material, making it possible to prevent the adherence of dust or fluff to a surface of a substrate over an extended period of time.

[0016] The conductive particulates include, for example, metals, such as Pd, Pt, Ru, Ag, Au, Ti, In, Cu, Cr, Fe, Zn, Sn, Ta, W, and Pb, or borides, such as HfB_2 , ZrB_2 , LaB_6 , CeB_6 , YB_4 , and GdB_4 , or carbides, such as TiC , ZrC , HfC , TaC , SiC , and WC , or nitrides, such as TiN , ZrN , and HfN , or semiconductors, such as Si and Ge, or carbon. An appropriate one can be selected from among the above.

[0017] Preferably, the antistatic layer has a resistance value ranging from 10^6 to $10^9 \Omega/\square$.

[0018] If the resistance value exceeds $10^9 \Omega/\square$, the electrical resistance will be excessively high, and the antistatic layer will no longer be able to sufficiently release electricity. This may prevent antistatic effect from being fully displayed.

[0019] A first projector in accordance with the present invention is provided with the electro-optical apparatus described above.

[0020] A second projector in accordance with the present invention is provided with a light source, a color separating optical system that separates a light beam emitted from the light source into a plurality of colors, a plurality of

09391406-062704

electro-optical apparatuses that modulate the color beams that have been separated by the color separating optical system, a prism that synthesizes the color beams that have been modulated by these electro-optical apparatuses, and a projection lens that projects light emitted from the prism, the electro-optical apparatuses having the construction described above.

[0021] In the projector according to the present invention, since the antistatic layer is formed on the surface of the substrate, even if static electricity is generated on the surface of the substrate, the static electricity escapes to the exterior of the apparatus through the antistatic layer. Thus, electrification to the surfaces of the substrates of the electro-optical apparatus can be reduced, making it possible to minimize the adherence of dust, fluff, or the like to the surface of a substrate. This minimizes deterioration of images caused by the adherence of dust, fluff, or the like during a manufacturing process or during the use by a user.

[0022] Moreover, the above feature obviates the need for or simplifies the work for removing dust, fluff, or the like from a substrate of an electro-optical apparatus and the need for equipment required therefor. Hence, the manufacture and maintenance of the electro-optical apparatus can be efficiently performed, and the cost required for the manufacture and maintenance can be reduced.

[0023] In addition, the need for dust-proof glass, which has hitherto been substantially essential, can be obviated. If the need for the dust-proof glass is obviated, then the number of components can be reduced, so that the manufacturing cost can be reduced from this respect also.

[0024] Furthermore, since the electrification to a substrate can be reduced, in the case of an electro-optical device equipped with a TFT (thin-film transistor) device or the like, the destruction of the TFT device attributable to electrical discharge can be prevented, and self-reproach defects in a manufacturing process can be reduced.

[0025] When the projector described above is equipped with a component formed of a synthetic resin, the component formed of a synthetic resin is preferably provided with antistatic treatment.

[0026] Providing the component made of a synthetic resin, which is prone to generate static electricity, with antistatic treatment, such as application of a surfactant, makes it possible to further securely prevent electrification in the projector. Hence, the dust or fluff brought in by static electricity generated in the component made of a

synthetic resin can be reduced. Thus, image deterioration of the projector can be further securely prevented, and the efficiency of manufacture and maintenance will be further enhanced.

5 [0027] The component made of a synthetic resin may be a holding frame installed around a liquid crystal panel.

[0028] Providing the holding frame with antistatic treatment makes it possible to prevent dust or the like on the holding frame from moving onto a surface of the substrate of an electro-optical apparatus, so that the adherence of dust or the like to a substrate can be further securely minimized.

10 [0029] Other projectors in accordance with the present invention include an optical element other than the substrate of an electro-optical apparatus, which is disposed in the vicinity of a focus of a projection lens, and which is provided with an antistatic layer or antistatic treatment.

15 [0030] Such an optical element may be a field lens disposed adjacent to a light source or an incident polarizer of an electro-optical apparatus, an emergent polarizer or prism disposed adjacent to a projection lens of the electro-optical apparatus, and a phase plate or a visual compensating film disposed adjacent to at least the light source or the projection lens of the electro-optical apparatus. If the incident polarizer, the phase plate, or the visual compensating film is disposed on a
20 light transmitting substrate formed of glass or the like in a bonded state, then such a light transmitting substrate corresponds to the foregoing optical element.

[0031] In the projectors having other configurations in accordance with the present invention, the same advantages as those obtained by forming the antistatic layer on a surface of the substrate of an electro-optical apparatus can be obtained by
25 providing at least one surface of such an optical element with an antistatic layer or antistatic treatment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032] Fig. 1 is a schematic diagram illustrating a structure of a projector according to an embodiment of the present invention;

30 Fig. 2 is a perspective view showing an exterior structure of an optical unit in the embodiment;

Fig. 3 is an exploded perspective view showing the structure of the optical unit in the embodiment;

Fig. 4 is a sectional view illustrating a section of the embodiment; and
 Fig. 5 is a flowchart illustrating a procedure for forming an antistatic layer.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0033] An embodiment of the present invention will be described with
 5 reference to the accompanying drawings.

[0034] (1) Basic structure of the projector

[0035] Fig. 1 shows the structure of a projector 100 according to an
 embodiment of the present invention. The projector 100 has an integrator
 illumination optical system 110, a color separating optical system 120, a relay optical
 10 system 130, liquid crystal panels 141R, 141G, and 141B, which are electro-optical
 apparatuses, a cross-dichroic prism 150 serving as a color synthesizing optical system,
 and a projection lens 160 serving as a projection optical system. These components
 are housed in an inner case 1000 made of a synthetic resin.

[0036] The integrator illumination optical system 110 is equipped with a
 15 light source device 111 that includes a light source lamp 111A and a reflector 111B, a
 first lens array 113, a second lens array 115, a reflecting mirror 117, and a
 superimposing lens 119. A light beam emitted from the light source lamp 111A is
 reflected by the reflector 111B so that it is condensed at a converging point, then
 formed into a substantially parallel beam by a concave lens 112 disposed at a position
 20 halfway to the converting point. The light beam is then divided into a plurality of sub-
 beams by the first lens array 113, and the sub-beams enter the second lens array 115.
 The sub-beams emergent from the second lens array 115 are polarized into one type of
 polarized beams by a polarization converting element 116. A specific configuration
 of such a polarization converting element has been disclosed in Japanese Unexamined
 25 Patent Application Publication No. 8-304739. The sub-beams that have been
 converted into one type of polarized beams by the polarization converting element 116
 are substantially superimposed on three liquid crystal panels 141 (liquid crystal
 panels 141R, 141G, and 141B for the respective colors) that make up an
 electro-optical apparatus 140, which will be discussed hereinafter.

[0037] The color separating optical system 120 equipped with two dichroic
 30 mirrors 121 and 122, and a reflecting mirror 123 functions to separate a plurality of
 sub-beams emitted from the integrator illumination optical system 110 into three color
 beams of red, green, and blue by the dichroic mirrors 121 and 122.

5

10

15

20

25

30

[0044] In the projector 100 set forth above, the electro-optical apparatus 140, the cross-dichroic prism 150, and the projection lens 160 are combined into an optical unit 170. More specifically, as shown in Fig. 2, the optical unit 170 is equipped with a head body 171 constituting a structure having an L-shaped side surface formed of a magnesium alloy.

[0045] The projection lens 160 is fixed by screws to the outer side of a vertical surface of an L-shaped member of the head body 171. The cross-dichroic prism 150 is also fixed by screws to the upper side of the horizontal surface of the L-shaped member of the head body 171.

[0046] The three liquid crystal panels 141R, 141G, and 141B are disposed to surround three side surfaces of the cross-dichroic prism 150. To be more specific, as shown in Fig. 3, the liquid crystal panels 141R, 141G, and 141B are housed in a holding frame 143 made of a synthetic resin, and pins 145 made of a transparent resin are inserted, together with an ultraviolet curing type adhesive agent, into holes 143A formed in the four corner portions of the holding frame 143. This secures the three liquid crystal panels 141R, 141G, and 141B in the proximity of the cross-dichroic prism 150 by the so-called POP (Panel On Prism) structure wherein they are adhesively secured to a beam incident end surface 151 of the cross-dichroic prism 150. The holding frame 143 has a rectangular opening 143B, the liquid crystal panels 141R, 141G, and 141B being exposed at the opening 143B, thus providing an image forming region. More specifically, the color beams R, G, and B are introduced to this portion of the liquid crystal panels 141R, 141G, and 141B to form an optical image based on image information.

[0047] (3) Antistatic layer and treatment layer

[0048] In this embodiment, as shown in Fig. 4, the liquid crystal panels 141R, 141G, and 141B are equipped with a pair of glass substrates 3a and 3b, and a liquid crystal 4, which is an electro-optical element sandwiched between the pair of substrates 3a and 3b. Antistatic layers 1 having a predetermined thickness (e.g. 100 to 200 nm) are provided on the outer surfaces of these substrates 3a and 3b.

[0049] The antistatic layers 1 are formed of an inorganic material, specifically, silica (SiO_2) and conductive particulates, and are transparent.

[0050] The conductive particulates include, for example, metals, such as Pd, Pt, Ru, Ag, Au, Ti, In, Cu, Cr, Fe, Zn, Sn, Ta, W, and Pb, or borides, such as HfB_2 , ZrB_2 , LaB_6 , CeB_6 , YB_4 , and GdB_4 , or carbides, such as TiC, ZrC, HfC, TaC, SiC, and WC, or nitrides, such as TiN, ZrN, and HfN, or semiconductors, such as Si and Ge, or carbon. An appropriate one can be selected from among the above.

[0051] The antistatic layers 1 have a resistance value ranging from 10^6 to $10^9 \Omega/\square$. If the resistance value exceeds $10^9 \Omega/\square$, the antistatic layers will no longer

be able to sufficiently release electricity, preventing antistatic effect from being fully displayed.

[0052] Treatment layers 2 that have been provided with antistatic treatment are formed on both surfaces of the holding frame 143 installed around the liquid crystal panels 141R, 141G, and 141B. The treatment layers 2 are formed by applying a surfactant to both surfaces of the holding frame 143 by a spray or the like, and it has a predetermined thickness. The treatment layer 2 is also formed on the inner surface of another component made of a synthetic resin, such as the inner case 1000.

[0053] Surfactants are roughly divided into the cationic type, the anionic type, the nonionic type, and the amphoteric type. Cationic surfactants include quaternary ammonium salt; anionic surfactants include aliphatic sulfonate, higher alcohol sulfate, and higher alcohol phosphate; nonionic surfactants include higher alcohol ethylene oxide, polyethylene glycol fatty ester, and polyhydric alcohol fatty ester; and amphoteric surfactants include betaine.

[0054] (4) Procedure for forming antistatic layers and treatment layers

[0055] In the process for manufacturing the projector 100 discussed above, the antistatic layers and the treatment layers are formed. The procedure for forming the antistatic layers and the treatment layers will be described in conjunction with the flowchart shown in Fig. 5.

[0056] First, the glass substrates 3a and 3b, which are the constituents for the TFTs making up the liquid crystal panels 141R, 141G, and 141B, are prepared (step S11). Then, TFT elements, predetermined electrodes, etc. are formed on the glass substrate 3a, and common electrodes, etc. are formed on the glass substrate 3b (step S12). Next, these glass substrates 3a and 3b are bonded (step S13), and a liquid crystal material 4 is sealed in therebetween (step S14). The antistatic layers 1 are formed on the surfaces of the panels thus completed (step S15). The antistatic layers 1 are formed by applying a material onto the substrates 3a and 3b by a roller or by any other appropriate method. Furthermore, the substrates 3a and 3b may be provided with anti-reflection layers, as necessary.

[0057] The antistatic layers 1 may be formed before step S11. In other words, the substrates 3a and 3b may be provided with the antistatic layers 1 in advance. The step for forming the antistatic layers 1 is preferably implemented in a

09591406-062701

clean room so as to prevent the adherence of dust or fluff in the step for forming the antistatic layers 1.

5 [0058] After the liquid crystal panels 141R, 141G, and 141B are completed by the steps described above, they are installed to the holding frame 143 (step S16). A surfactant is applied to the surfaces of the holding frame 143 beforehand. In other words, the antistatic treatment may be provided in advance.

10 [0059] Meanwhile, a surfactant is applied to the inner surface of a component of the projector 100, which is made of a synthetic resin, and which is, for example, the inner case 1000, to form the treatment layer 2. More specifically, the inner surface of the inner case 1000 is provided with antistatic treatment.

[0060] Thereafter, the components, such as the inner case 1000 provided with the antistatic treatment, and the liquid crystal panels 141R, 141G, and 141B are combined to assemble the projector (step S17), thereby completing the projector 100.

15 [0061] In this embodiment, an alternative method may be adopted wherein the holding frame 143 is attached to the liquid crystal panels 141R, 141G, and 141B, then a surfactant is applied to the holding frame 143.

[0062] (5) Advantages of the embodiment

[0063] The embodiment described above provides the following advantages.

20 [0064] Since the antistatic layers 1 are formed on both outer surfaces of the pair of the substrates 3a and 3b, even if static electricity is generated on the surfaces of the substrates 3a and 3b, the static electricity escapes to the outside through the antistatic layers 1. Thus, electrification to the substrates 3a and 3b can be reduced, making it possible to prevent the adherence of dust, fluff, or the like to the surfaces of the substrates 3a and 3b. This allows deterioration of images caused by the adherence of dust, fluff, or the like during a manufacturing process or during the use by a user to be minimized.

25 [0065] Moreover, the above feature obviates the need for or simplifies the work for removing dust, fluff, or the like from the substrates 3a and 3b and the need for equipment required therefor. Hence, the manufacture and maintenance after the manufacture of the liquid crystal panels 141R, 141G, and 141B, and the
30 projector 1000 can be efficiently performed, and the cost required for the manufacture and maintenance can be reduced.

5 **[0067]** Furthermore, since the electrification to the substrates can be reduced, the destruction of the TFT devices attributable to electrical discharge can be prevented, and defects in a manufacturing process can be reduced.

15 [0069] The component made of a synthetic resin is the holding frame 143
installed around the liquid crystal panels 141R, 141G, and 141B. Hence, providing
the holding frame 143 with antistatic treatment makes it possible to prevent dust or
the like on the holding frame 143 from moving onto the surfaces of the substrates of
an electro-optical apparatus, so that the adherence of dust or the like to a substrate can
20 be further securely minimized.

25 [0071] (6) Modification of the embodiment

[0073] In the foregoing embodiment, the antistatic layers have been provided on the substrate surfaces of the liquid crystal panels 141R, 141G, and 141B, which are the electro-optical apparatuses, and the antistatic treatment is provided on the holding frame 143 of the liquid crystal panels 141R, 141G, and 141B, and on the inner surface of the inner case 1000. Alternatively, however, at least one of the antistatic layer and the antistatic treatment may be provided on other optical elements

disposed in the vicinity of the back focus position of the projection lens 160.

Providing the antistatic layers 1 or forming the treatment layers 2 by antistatic treatment on those other optical elements makes it possible to prevent the images of dust or the like from being projected, and also to reduce the manufacturing cost of the projector 100. Furthermore, when subjecting those other optical elements to inspection, if the surfaces of the other optical elements are wiped with a rag or the like moistened with an antistatic agent (an inorganic material for forming the antistatic layers 1 or a surfactant for providing the antistatic treatment) before mounting them on an inspecting machine, then an advantage will be obtained in which the surfaces can be cleaned and also the adherence of dust or the like can be minimized.

[0074] Such other optical elements include, for example, the field lenses 139R, 139G, and 139B, an incident polarizer (not shown) disposed between the field lenses 139R, 139G, and 139B and the liquid crystal panels 141R, 141G, and 141B, an emergent polarizer (not shown) disposed between the liquid crystal panels 141R, 141G, and 141B and the cross-dichroic prism 150, and a light incident surface of the cross-dichroic prism 150. As necessary, a phase plate (not shown) or a visual compensating film or the like, which is not shown, for enhancing contrast may be provided between the incident polarizer and the field lenses 139R, 139G, and 139B or in an optical path between the emergent polarizer and the cross-dichroic prism 150. These phase plate and the visual compensating film may be included in the foregoing other optical elements.

[0075] Regarding the optical elements, such as the field lenses 139R, 139G, and 139B, and the cross-dichroic prism 150, that are constructed by lenses or prisms, the antistatic layer 1 or the antistatic treatment may be directly formed on at least one surface thereof. To provide the antistatic layer 1 or the antistatic treatment on a plate-like or film-like optical element, such as a polarizer, a phase plate, or a visual compensating film, several different methods set forth below are conceivable.

[0076] According to a first conceivable method, an antistatic layer or antistatic treatment is directly provided on at least one surface of such an optical element.

[0077] According to a second conceivable method, if such an optical element is mounted on a light transmitting substrate or other optical component, such as a lens or a prism, then the antistatic layer 1 or the antistatic treatment is provided on

the opposite surface of the optical component from the surface on which such an optical element is attached. In this case, the optical element may further be provided with the antistatic layer 1 or the antistatic treatment. If the optical element is retained on a holding frame or the like, then the holding frame is preferably provided with an antistatic layer or the antistatic treatment also.

[0078] If these optical elements are attached to the surfaces of the substrates of liquid crystal panels, then the antistatic treatment on the substrates of the liquid crystal panels may be omitted by providing the optical elements with antistatic layers or antistatic treatment.

[0079] Preferably, the antistatic layers or antistatic treatment is provided on all optical elements disposed in the vicinity of the back focus position of the projection lens 160; however, the advantage described above can be fully obtained simply by providing the antistatic layer or antistatic treatment only on the optical element disposed in a portion especially prone to influence an image.

[0080] In the foregoing embodiment, the antistatic layers 1 formed on the liquid crystal panels 141R, 141G, and 141B are formed of an inorganic material. In the present invention, however, the antistatic layers 1 may alternatively be formed of an organic material, and the surfactant applied to the surface of a component made of a synthetic resin may alternatively be applied to the surfaces of the liquid crystal panels 141R, 141G, and 141B. In this case, whatever material may be used for the antistatic layers 1 to be provided on the surfaces of the liquid crystal panels 141R, 141G, and 141B, the material should be transparent.

[0081] In the foregoing embodiment, the antistatic treatment on the component made of a synthetic resin has been performed using a surfactant; however, the same inorganic material as that of the antistatic layers 1 may be used on the surface of the component made of a synthetic resin.

[0082] The antistatic layers 1 formed on the liquid crystal panels 141R, 141G, and 141B may be provided on at least the surfaces opposing the prism 150, and may not necessarily have to be provided on both surfaces thereof. If, for example, the antistatic layers 1 are provided only on the surfaces of the liquid crystal panels 141R, 141G, and 141B that oppose the prism 150, then even if dust or fluff adheres to the surfaces of the liquid crystal panels 141R, 141G, and 141B that are on the opposite side from the prism 150, the dust or fluff can be easily removed by a blower or the

like because a larger space can be secured on this side since the prism 150 is not provided.

[0083] Similarly, the antistatic treatment on the holding frame 143 does not necessarily have to be performed on both surfaces; the antistatic treatment may be provided at least on the surface thereof that opposes the prism 150.

[0084] The antistatic layer 1 does not necessarily have to be formed on the liquid crystal panels 141R, 141G, and 141B; it may alternatively be formed on another electro-optical apparatus, such as an optical modulating apparatus employing a plasma element or a micro mirror, or an organic EL apparatus.

[0085] The specific structures, configurations, etc. of the present invention may vary within the scope wherein the object of the present invention can be attained.

[0086] As described above, according to the present invention, the electrification to the substrate of an electro-optical apparatus can be reduced, making it possible to prevent dust, fluff, or the like from adhering to the surface of the substrate. Hence, the deterioration of images caused by the adherence of dust, fluff, or the like during manufacture or the use by a user can be minimized.

[0087] Accordingly, the work for removing dust, fluff, or the like from a substrate of an electro-optical apparatus and the equipment therefor is no longer necessary or can be simplified. Hence, the manufacture and maintenance after the manufacture can be efficiently performed, and the cost required for the manufacture and maintenance can be reduced.